

Organic Synthesis From Above: Laboratory Studies of Haze Particles in Simulated Early Earth Atmospheres

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Photochemistry in the atmosphere of the early Earth may have led to the formation of complex organic molecules, similar to those observed in the haze layer on Saturn's moon Titan. Due to differences in atmospheric chemistry, the aerosols formed on the early Earth may have had distinct chemical properties from those suspected to make up the hazes on Titan. The flux of gases such as CH₄ and CO₂ as well as possibly elevated levels of H₂ could have created a myriad of organic products with complex functional groups beyond simple hydrocarbons. Despite the implications of such a haze layer, there have been few laboratory studies of the organic material produced under possible early Earth conditions.

To simulate particle production in the early Earth's atmosphere, we use a deuterium lamp with a spectral range from 115 - 400 nm to irradiate gaseous mixtures of CH₄, CO₂, H₂, and N₂. We use a novel analysis technique, the Aerosol Mass Spectrometer (AMS), to study the chemical composition and size of the particles produced as a function of initial trace gas composition. Ongoing studies explore the chemical and physical properties of these aerosols as a function of C/O and H₂/C ratios as well as other experimental parameters such as total pressure. We have also used a Scanning Mobility Particle Sizer (SMPS) in conjunction with the AMS to give complementary information about the morphology of these haze particles, which can have important impacts on the optical properties. Microscope imaging has provided confirmation of the aerosol shapes inferred from these experimental techniques. The properties of the haze aerosols formed using the UV lamp are also compared to those from previous studies using an electrical discharge excitation source.

We have studied a variety of gas mixtures from CH₄/CO₂ ratios of 5 down to 0.2, and we have found that the chemical composition of the aerosols depends strongly on the trace gas composition. Most notably, we find that as the amount of CO₂ relative to CH₄ is increased, the particle composition transitions from a hydrocarbon product to molecules with oxygenated functional groups. When H₂ is included in the gas mixtures at concentrations up to 15% by volume, we see additional compositional effects including an increase in aromatic structures. Under all of these conditions studied, some level of aerosol production has been observed, thus indicating that a haze layer on the early Earth may be likely even as the atmosphere was evolving. To quantify haze production, we have measured the photon flux of our UV source. In combination with the quantitative data provided by the AMS we are able to estimate a rate of aerosol production as a function of starting gas composition. We will show that the amount of haze produced is expected to serve as a significant source of organic material to the early Earth.